Energy Overview

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There is no doubt that the energy problems facing our country and the world are the least understood and the most complex and challenging problems that our Nation has ever faced. The solutions will require the best efforts of all facets of the American system: Government, business, industry, the university community, and, indeed, every one of us.

In this paper attention is focused on how NASA Lewis is using its experience, capabilities, and facilities in support of energy programs being conducted by the Department of Energy (DOE) and other agencies. First, however, some background information is presented regarding NASA's involvement in solving some of our energy problems. Then our energy technology effort here at NASA Lewis is briefly reviewed. Subsequent papers give more detail on specific energy projects at Lewis.

NASA's energy technology objective is to apply our knowledge in aeronautics and space technology, our management expertise, and our facilities to the research and development needs of the DOE and other agencies. The NASA Centers involved are the Lewis Research Center, the Marshall Space Flight Center, and the Jet Propulsion Laboratory. An obvious question is, Why and how is the Space Agency involved in solving ground-based energy problems? NASA energy involvement is mandated by Congress and needed by DOE. Starting with the OPEC oil embargo in 1973-74 Congress has passed a number of energy bills, and, since in the eyes of Congress NASA was and is a *can-do agency*, NASA participation was written into many of the bills and the National Aeronautics and Space Act was amended three times: in 1974 by the Solar Energy, Resources, Development & Demonstration Act, in 1976 by the Electric & Hybrid Vehicle R&D Act, and in 1978 by the Automotive Propulsion R&D Act. Currently the basic working relationship between DOE and NASA is guided by the Memorandum of Understanding signed by both agencies in June 1975, which states that "it is the policy of DOE and NASA to identify specific program tasks which can be undertaken by the NASA Centers in support of DOE programs to the benefit of both agencies and the Nation."

The NASA activities in support of the National Energy Research, Development, and Demonstration (RD&D) program consist of reimbursable programs conducted by NASA for other agencies and NASA-funded programs. In this regard, NASA Lewis is reimbursed by three agencies: the Department of Energy, the Department of Interior, and the Agency for International Development. NASA funds (seed money) are specifically used to investigate the application of existing in-house capabilities to attacking a given energy-related problem. If the investigation proves to be successful, a plan to solve the problem is developed and submitted to the agency having cognizance over the particular energy area. If the agency accepts the plan, a transfer of funds takes place and a reimbursable project is then undertaken. Total reimbursable energy funding transferred to NASA this fiscal year by DOE and other agencies was about $250 million, of which Lewis received about $130 million. About 95 percent of the funding was from DOE.

It is the objective of the DOE-NASA energy program to ensure that U.S. Government-developed technology is available to all U.S. industries. One way this is done is by involving industries in programs as participants. About 85 percent of our funding is spent on outside contracts and grants.

We also document the technology developments and disseminate the documented material in technical meetings, conferences, and workshops. An example of the workshops NASA conducts was the one held on May 14, 1980, in Tuscon, Arizona—the National Conference on Photovoltaic Opportunities for Electrically Powered Products. The presentations and discussions during the workshop covered practical information about solar photovoltaics and their application to commercial products as well as existing and potential domestic and international markets for photovoltaic-powered products. Since the early 1970's, NASA Lewis has been utilizing its many and unique capabilities that were developed to solve aeronautics and space problems to make meaningful contributions to solving certain energy problems. Lewis is the only power and propulsion technology center in the U.S. Government. There are major "in-place" energy-related technologies such as materials and metallurgy, combustion, lubrication and wear, bearings and engine seals, compressors and turbines, magnetohydrodynamics, electrochemistry, photovoltaics (solar cells), thermodynamics, heat transfer, system dynamics, and system analysis. The current energy activities at Lewis are in two broad areas—automotive propulsion systems technology and stationary power. These activities could also be described in terms of conservation of energy (propulsion system technology), switch to coal (stationary-power energy conversion), and new energy sources (wind, photovoltaics). A brief overview of our major energy activities is given here.

Automotive Propulsion Systems Technology

As a result of Congressional legislation, the DOE has implemented a program, to significantly reduce the Nation's dependence on petroleum, that may result in an alternative automotive engine in the 1990's with high fuel economy and clean exhaust. The goal of this program, for which NASA Lewis has project management responsibility, is to provide the technology base within the automobile industry to support production development of alternative automotive engines that show

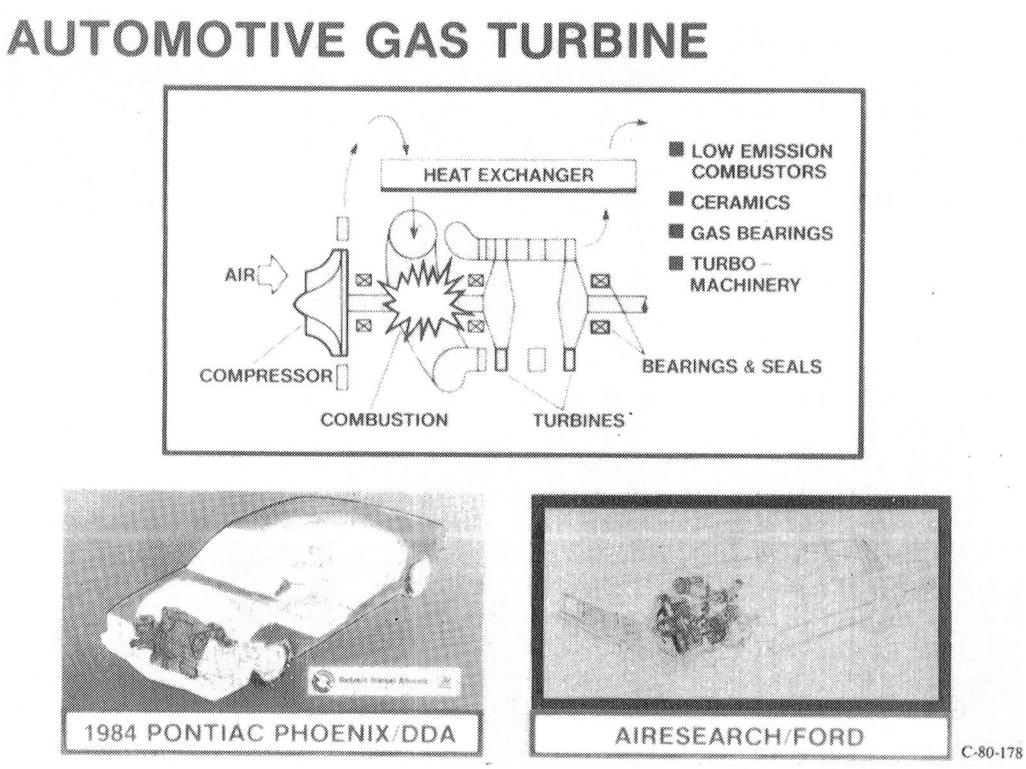

Figure 1

at least 30-percent improvement in fuel economy over future spark ignition internal combustion engines; that meet emission standards; that can use petroleum, nonpetroleum, or blends of fuels; and that can be sold competitively. Two external combustion engines, the gas turbine and the Stirling engine, show promise for meeting this goal. It is hoped that at the end of this Government/industry effort, in the mid-1980's, the automotive industry can make a decision to proceed into production engineering with either the gas turbine or the Stirling engine, or both. Two cost-sharing contracts for gas turbine engine development (fig. 1) were awarded in October 1979 to two teams: General Motors (Detroit Diesel Allison and Pontiac) and AiResearch/Ford. These two 6-year contracts are funded at about $60 million each. There is more discussion of this effort in M. H. Krasner's paper.

Another aspect of gas turbine engine development, shown in figure 2, is a demonstration effort to support the commercialization of gas turbine technologies. Five gas-turbine, intercity transit buses will soon be in revenue service in the City of Baltimore, and four intercity Greyhound buses are in revenue service out of Washington. Also shown is a gas-turbine-powered truck that is driven for demonstration purposes only. In each case the gas turbine engines are being compared in performance and reliability with the diesel engines that had powered the buses and the truck.

One cost-sharing contract, valued at about $90 million, was awarded to the team of Mechanical Technology Incorporated/United Stirling of Sweden/American Motors General for development of a Stirling automotive engine (fig. 3). Shown is a Stirling engine in an American Motors Spirit that is used for demonstration. Once again, more about this engine is given in Krasner's paper.

In September 1976, Congress passed the Electric and Hybrid Vehicle Research, Development, and Demonstration Act, which DOE is implementing and for which we are providing support in propulsion system research and development. The overall goal of this important program is to accelerate the commercialization of vehicles that use electricity as the principal source of propulsion energy and thus to provide fuel flexibility for the transportation sector. The research and development goal is to advance electric and hybrid vehicle technology to improve cost effectiveness, performance, and reliability. Propulsion systems are the responsibility of the Lewis Research Center;

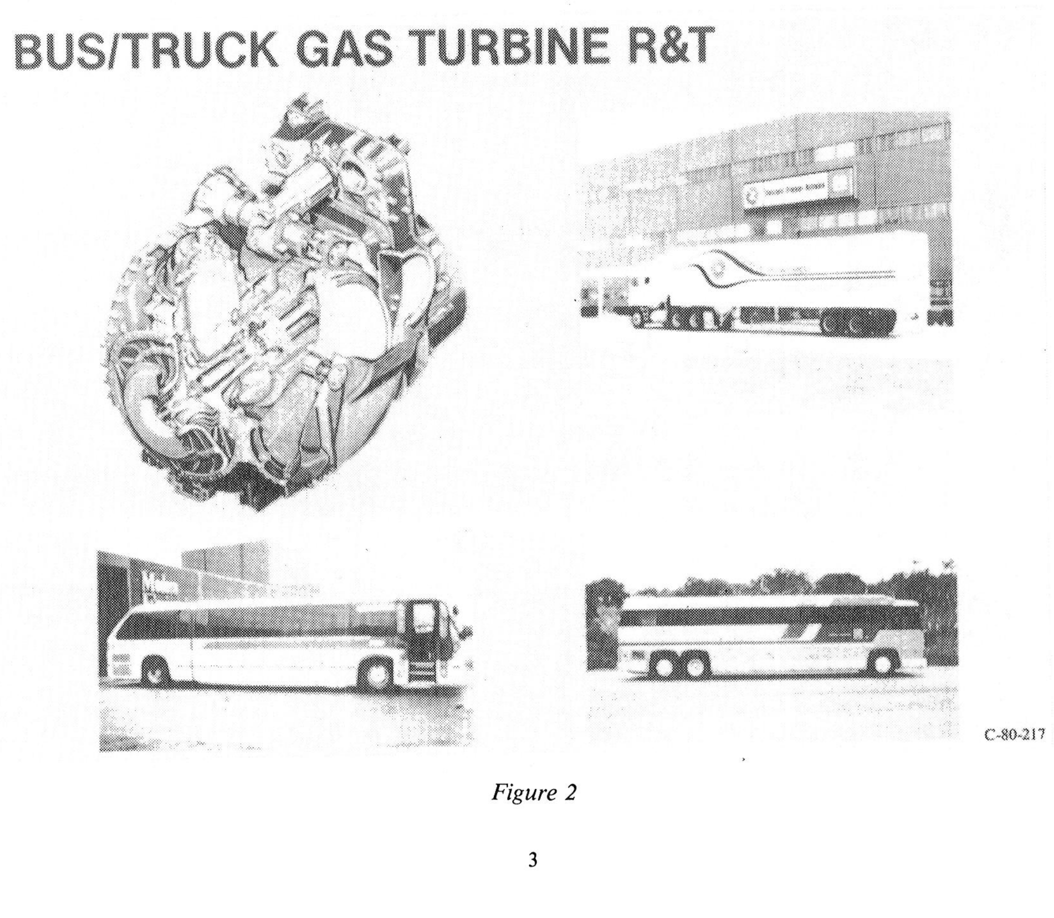

Figure 2

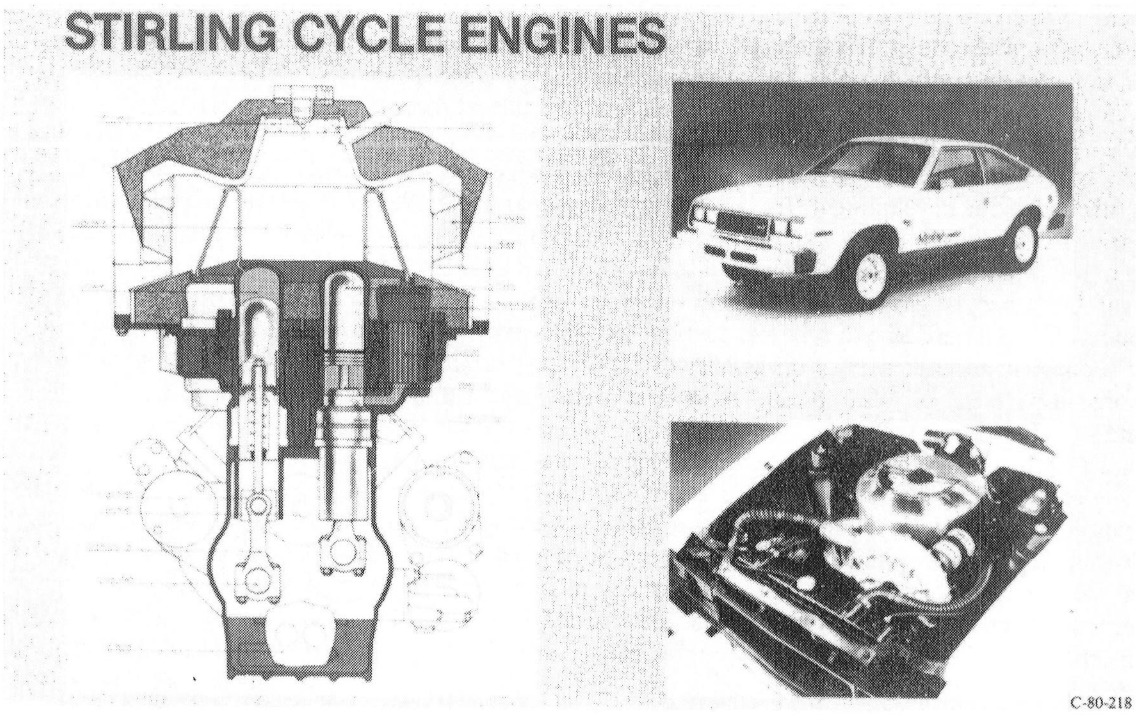

Figure 3

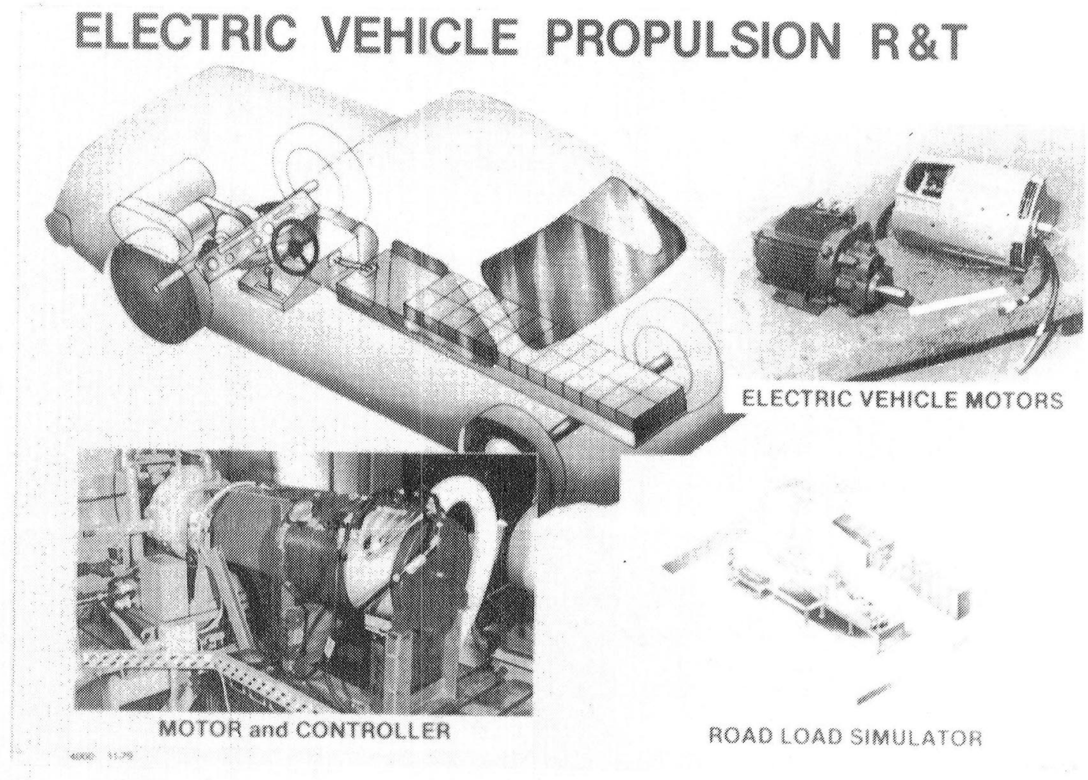

Figure 4

vehicle systems, of the Jet Propulsion Laboratory; and batteries, of ANL. Some of our propulsion system activity here at Lewis is shown in figure 4. There is further discussion of this program in H. J. Schwartz's paper on electric vehicles.

Stationary-Power Conversion

Wind and Solar Energy

It is becoming generally recognized that wind energy will be the first of the solar electric technologies under development to emerge for serious consideration as a utility power generation source. The goals of the DOE Federal Wind Energy program, which started in 1973, are to accelerate the development, commercialization, and utilization of reliable and economically viable wind energy systems, to make wind energy a viable technological alternative to other forms of energy, to pursue a course that will result in the production of significant amounts of electricity, and to create a competitive industry that produces wind turbines. NASA Lewis has project management responsibility for large, horizontal-axis wind turbines and the associated supporting research and technology. Figures 5 and 6 show the size and location of some of the large wind turbines managed by Lewis. The rotors of these machines turn at about 35 to 40 revolutions per minute (rpm), operate in winds between 8 and 35 mph, and provide enough power for about 500 average homes (Mod-1) or 100 average homes (Mod-0A). The Mod-0A at Clayton, New Mexico, has been operating since early 1978; and the Mod-1 at Boone, North Carolina, began its initial rotation in the summer of 1979. Another Mod-0A machine began operation in Hawaii in May 1980. The Mod-2 will begin operation later in this year in the state of Washington. Wind power commercialization is discussed in W. H. Robbin's paper.

Lewis is also managing a program for the Department of Interior wherein a megawatt-size wind turbine will be operated in conjunction with a hydroelectric dam (for storage) in Wyoming.

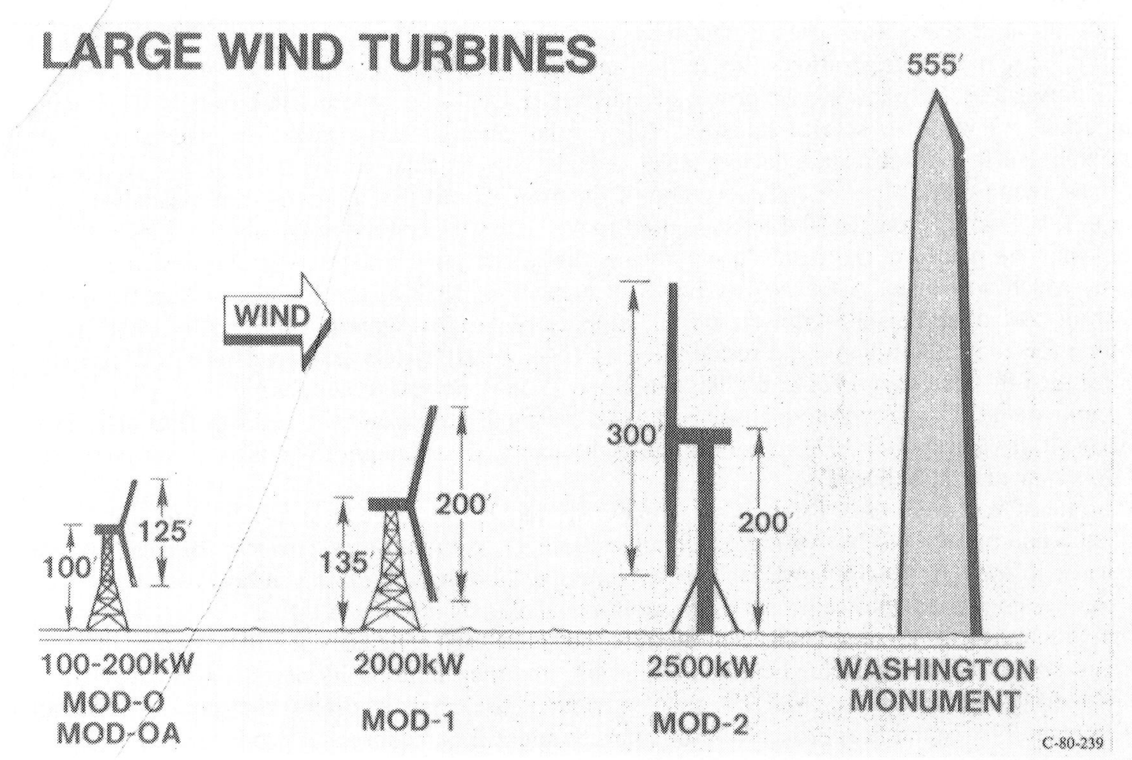

Figure 5

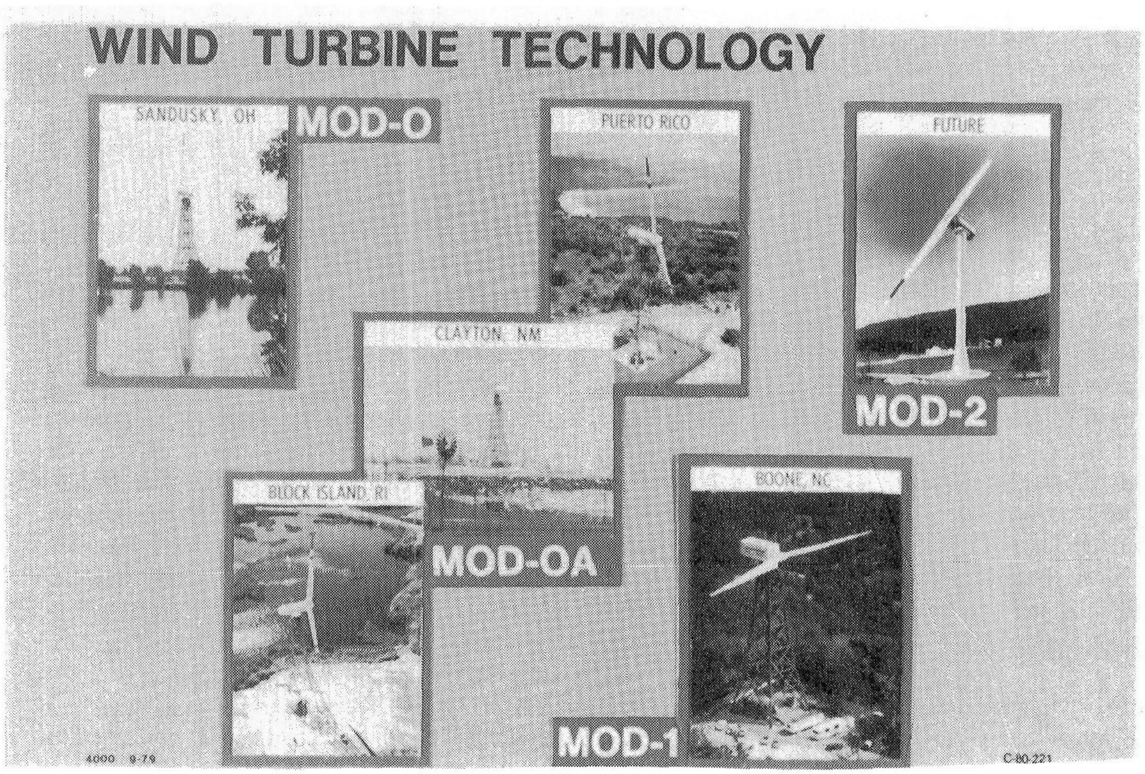

Figure 6

NASA Lewis solar photovoltaic activities are funded by DOE and the Agency for International Development (AID). These projects are to demonstrate in the field that photovoltaic power systems are suitable and ready for specific near-term applications such as village power systems, water pumping, irrigation, refrigeration of medicines and food, and lighting. Since 1976, NASA Lewis has installed over 35 solar photovoltaic power systems for various applications and power levels ranging from about 50 watts to several kilowatts. (The solar photovoltaic conversion process uses the photovoltaic effect in solid-state devices (solar cells) to convert solar energy directly into electricity, with no moving parts.) Figure 7 shows some of the applications that Lewis is responsible for. The System Test Facility, located at Lewis, is used to test solar arrays and solar photovoltaic systems before they are placed in the field. Also shown is the world's first village solar photovoltaic power system, which was installed by NASA Lewis in November 1978 at the Papago Indian village of Schuchuli, Arizona. This 3.5-kilowatt system supplies power for lighting, refrigeration, and water pumping for about 95 Indians who reside there. A 1.8-kilowatt system (as part of our AID project) was installed in December 1978 at a village in Upper Volta, Africa, to supply power to grind grain and pump water. The fire lookout tower in Lassen National Forest and the highway dust sign have been operating since early 1977. There is more discussion of solar photovoltaics in the paper by R. G. Forney and J. N. Deyo.

As some of you are aware, Public Law 95-620 requires that most Federal installations stop using petroleum and natural gas by 1990. Also, in all probability, many utilities currently using petroleum will switch to coal. At NASA Lewis we are developing technology along with industry for the use of coal to fuel coal-fired fuel cells, MHD generators, and turbines (fig. 8). Fuel cell systems offer attractive features for commercialization because they have high efficiency at full or part load, they are clean and quiet, they provide heat and electricity, and their modularity permits multikilowatt to multimegawatt power levels. MHD's chief attributes are that it offers the potential of an environmentally acceptable approach to using our abundant coal resources to produce electric power at very high efficiency (e.g., a potential 50 percent improvement over current steam plants) and attractive costs. The heat engine effort is directed toward advancing the technology for gas turbines,

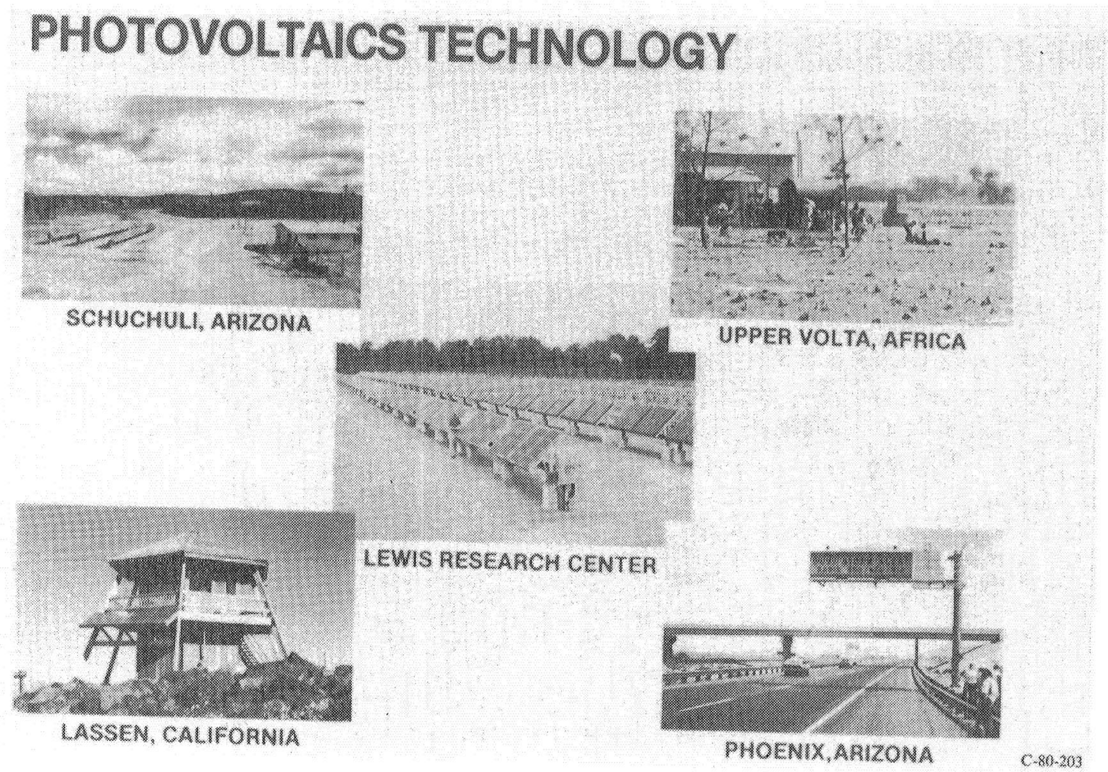

Figure 7

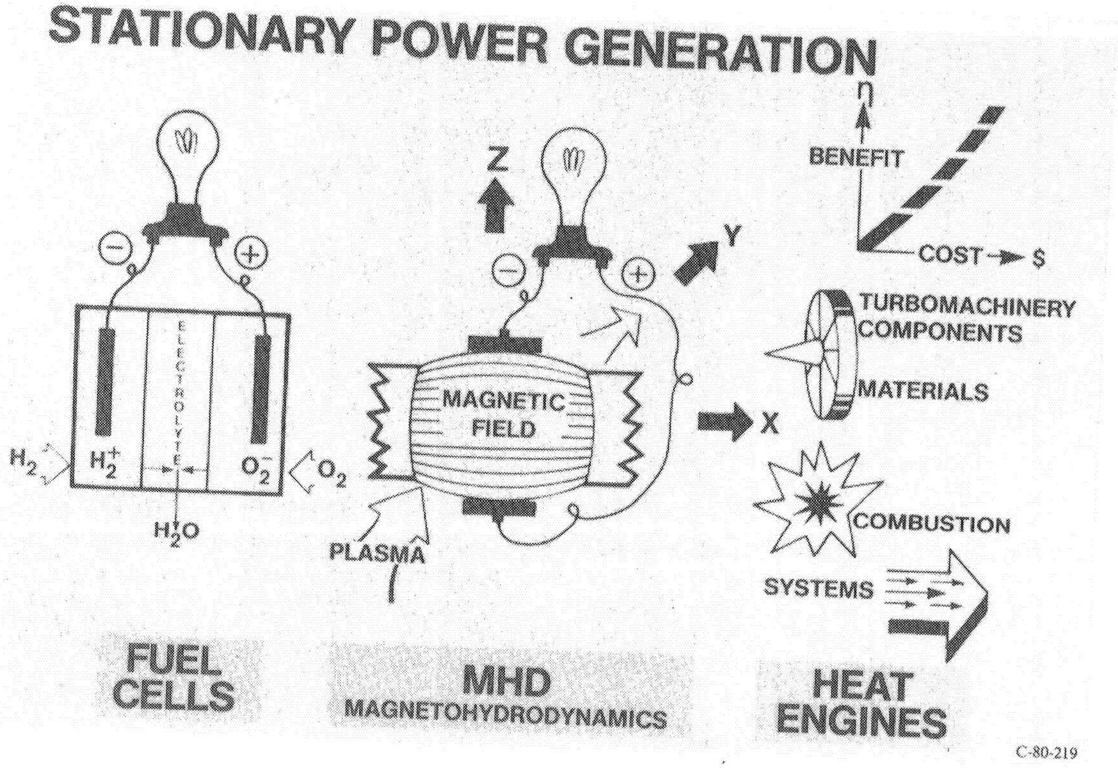

Figure 8

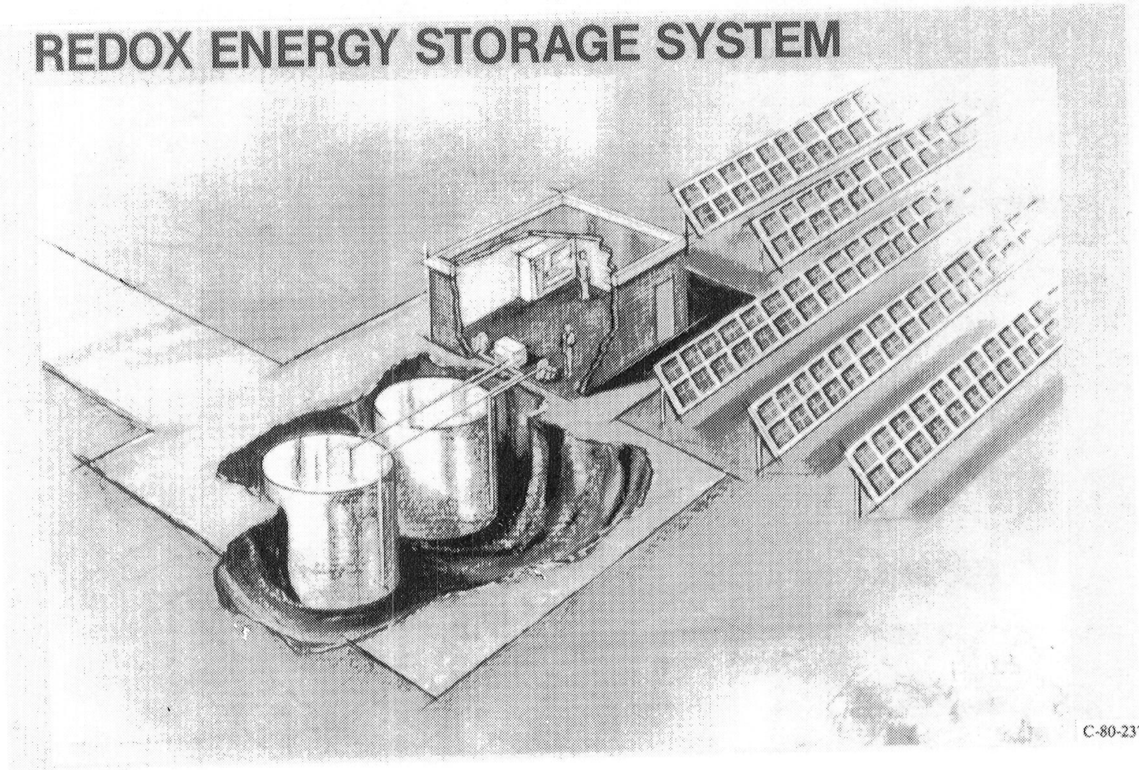

Figure 9

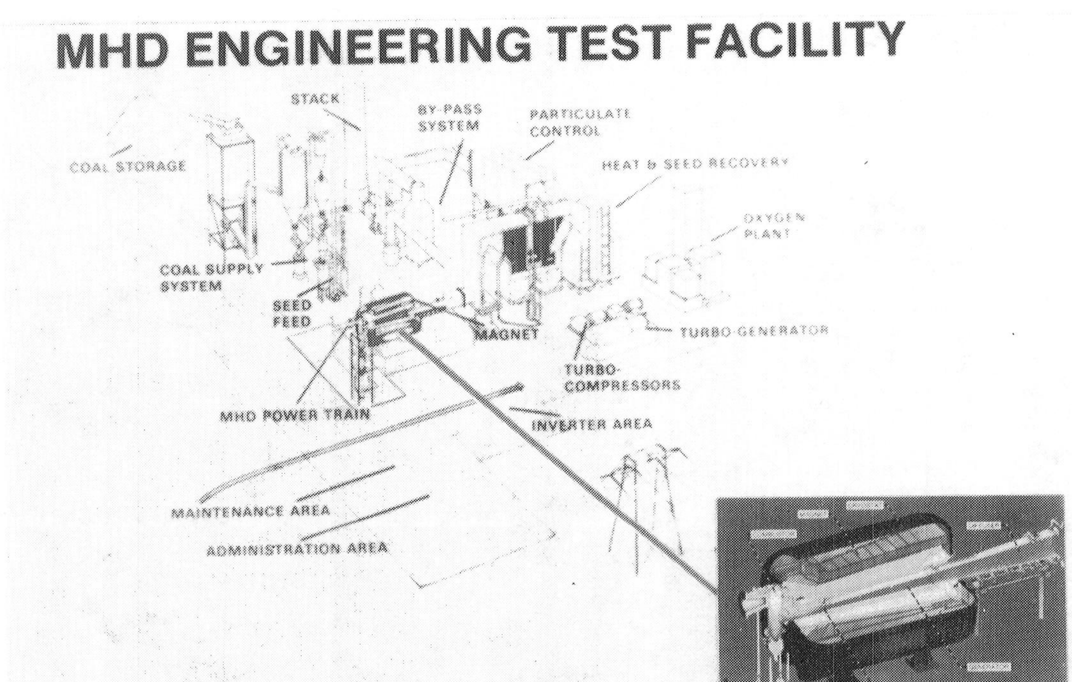

Figure 10

so that they can be used with coal or coal-derived fuels. The objectives of these three projects are

(1) For fuel cells—to develop commercially viable phosphoric acid fuel-cell systems for electric utility power generation and on-site/integrated energy systems for residential, commercial, and industrial applications.

(2) For magnetohydrodynamics (MHD)—to develop advanced MHD power train technology and to define the design of a commercial prototype plant (engineering test facility) directed toward determining the commercial viability of coal-fired MHD powerplants having potential for high plant efficiency and low cost of electricity.

(3) For heat engines—to do system studies and to develop near-term combustion and materials technology for turbine powerplants in order to shift from natural gas and oil to coal and coal-derived fuels. Figure 9 shows an on-site commercial application for a fuel cell, and figure 10 shows the MHD engineering test facility that is planned to demonstrate the feasibility of MHD for a utility application. Unique MHD systems are the power train, the magnet, and the heat and seed recovery system. (MHD is a process in which fuel is heated to such a high temperature that it becomes ionized. By passing this high-temperature gas through a channel surrounded by strong magnets, the electrons in the gas can be collected, thus yielding electrical energy.) The paper by L. I. Shure discusses a unique concept for burning Ohio high-sulfur coal here at Lewis.

Energy Storage

Energy storage is an essential element to many energy conversion systems. For example, solar energy must be stored when the Sun is not shining and wind energy when the wind is not blowing. One interesting and promising concept of energy storage, conceived here at Lewis in 1973 and currently being evaluated, is shown in figure 11. Redox is an acronym which stands for reduction oxidation. Chemical energy is converted into electrical energy when two reactant fluids—chromium chloride and iron chloride—interact through a thin membrane. There is further discussion of this system by L. H. Thaller.

This paper briefly touched on NASA's involvement, especially here at Lewis, in solving our energy problems.

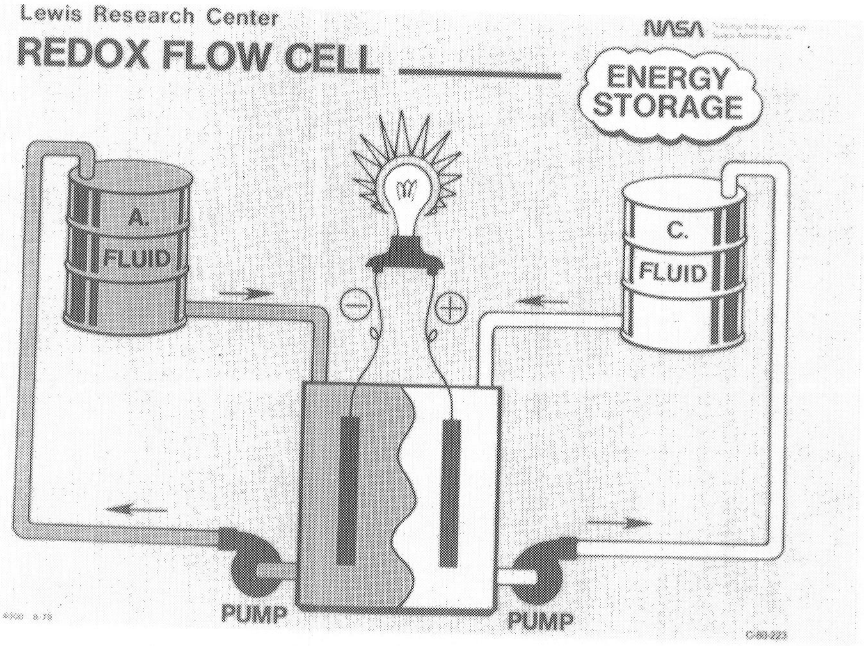

Figure 11